Species composition and growth of eucalypt regeneration in eastern Tasmania at age 21–22 years after clearfelling

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Abstract

Eucalypt regeneration established on long-term study plots in 1980–81 following harvesting of mature dry eucalypt forest was recently assessed for composition of eucalypt species and growth. Eucalypt stocking on the plots ranged from 701–3613 stems/ha, a 4.9–54.3% reduction from stockings recorded at an earlier assessment (age 9–10 years). Species composition has changed in some plots since the earlier assessment but on most plots is still generally closer to that of the unlogged forest than to that of the sowing mix used to regenerate the coupes. This is particularly so on peppermint/gum sites which were sown with ash species. Even though Eucalyptus globulus *was also included as 25–30% of the sowing mix on some of these sites, it was either absent or present at very low levels in the regenerated stands. It is important to recognise the natural occurrence of species in areas to be harvested and to apply management systems which will deliver the natural pattern, particularly where strong site/species relationships are evident.*

Growth on these predominantly low productivity sites (PI type E3- to E4, potential height classes 27–34 m, 15–27 m) has been slow, with volumes per hectare at age 21–22 years of 25.5–117.8 m^3 and MAIs of 1.2–5.6 m^3/ha/yr. Mean dominant heights of the regeneration ranged from 9.4 to 16.3 m, indicating a site index range of 15.2 to 26.1. The basal area of the regeneration at age 21–22 years is now an average of 36.1% (range 16–49%) of that of the unlogged forest assessed on the plots before harvesting.

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Introduction

In 1977–78, twelve plots were established in dry eucalypt forests in eastern Tasmania in order to compare eucalypt species composition and productivity of the unlogged forest with that of the subsequent eucalypt regeneration following harvesting. This comparison was part of a larger study of the effects of clearfelling and burning on vegetation and its associated insect fauna over the long term (i.e. at least 20 years). This research commenced in response to public concern over forest operations associated with the woodchip industry (Senate Standing Committee on Science and the Environment 1977).

Elliott *et al.* (1991) reported on the species composition, stocking and growth of the eucalypts on these plots at age 9–10 years. They found that the composition of eucalypt regeneration greater than 5 cm diameter at breast height over bark (DBH) was generally closer to that of the forest prior to logging than to that of the sowing mix used to regenerate the stand. This was

Table 1. Site descriptors for the logging units (coupes).

Coupe	Location[1]	Altitude a.s.l. (m)	Rainfall (mm)[2]	Parent material	Dominant eucalypt species
Swanport 048 (SW48)	Nugent EN 543 940	320	585	Triassic sandstone	*E. obliqua* *E. amygdalina* *E. viminalis*
Mt Connection 033 (MC33)	Little Swanport EP 668 392	580	900	Jurassic dolerite	*E. delegatensis* *E. amygdalina*
Tooms 054 (TO54)	Little Swanport EP 762 473	460	849	Jurassic dolerite	*E. obliqua* *E. tenuiramis*
Elephant 010[3] (EL10)	Break O'Day FP 030 837	300	686	Jurassic dolerite	*E. sieberi* *E. obliqua*

[1] 1:100 000 *Tasmap* reference.

[2] Mean annual rainfall at the nearest meteorological station.

[3] EL10 is the same coupe as EL7 referred to in the report of the previous assessment (Elliott *et al.* 1991); the name was changed between measurements.

particularly true for some peppermint/gum sites even though the sowing mix falling on these sites was often biased towards the ash species rather than proportionately representative of the species composition of the original forest.

This paper reports on a later age (21–22 years) assessment of the silvicultural regeneration on these same plots conducted to determine any changes in species composition since the previous assessment and to provide later age data on eucalypt growth in these dry forests. The species composition of regenerated forests is one of the factors used to determine the success of the regeneration effort under Indicator 2.1g of the Montreal Process criteria and indicators of sustainable forest management in Australia (MIG 1998).

Methods

Plot establishment

Three plots were established in each of four proposed logging coupes containing mature dry eucalypt forest in eastern Tasmania. The location and basic descriptors of these forests are summarised in Table 1 and Figure 1. Plot size was 75 m x 50 m (0.375 ha), with the corners marked by wooden pegs and wire stakes. Within each coupe, the three plots were located to sample a range of dominant eucalypt associations which were usually strongly related to aspect.

The coupes containing the plots were clearfelled, burnt and then aerially sown with eucalypt seed in 1980–81. Following the harvesting and regeneration treatments, plots were re-established in the same locations by replacing the wooden stakes and wire pegs with permanent steel star pickets for corner markers. Due to rescheduling of harvesting operations, one plot (TO54/1) was not harvested and one (EL10/3) was harvested but not burnt. All plots have remained unburnt since establishment except SW48 plots 1 and 2 which received light fire damage in the mid 1980s.

Vegetation

The plots were located in natural forests which can largely be classified as shrubby understorey dry eucalypt forest (Duncan and Brown 1985). Jurassic dolerite is the parent material on coupes MC33, TO54 and EL10, and Triassic sandstone occurs on SW48. The plots had an overstorey of

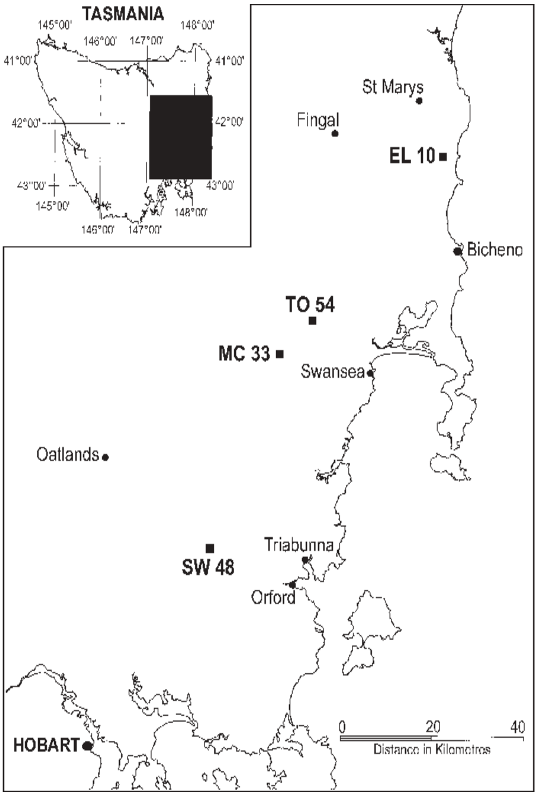

Figure 1. Location of the harvesting units (coupes).

eucalypt associations comprising two or more of the following species: *Eucalyptus amygdalina* Labill., *E. obliqua* L'Hérit., *E. delegatensis* R. Baker, *E. pulchella* Desf., *E. globulus* Labill., *E. ovata* Labill., *E. sieberi* L. Johnson, *E. tenuiramis* Miq. and *E. viminalis* Labill. (Table 1). These were relatively open forests with the stocking of mature eucalypt stems ranging from 109 to 339 stems / ha (Elliott *et al.* 1991).

The understorey stratum was characterised by short (up to 4 m), often prickly shrubs with a significant grassy / sedgy component in some areas. Seventy-two species of dicotyledons, 24 monocotyledons and five fern species were recorded across all the study areas before logging commenced. The most common plant families and genera present were Fabaceae (*Pultenaea*), Mimosaceae (*Acacia*), Proteaceae (*Banksia, Lomatia*), Asteraceae (*Olearia, Senecio*), Epacridaceae (*Epacris*), Xanthorrhoeaceae (*Lomandra*) and Poaceae (*Poa, Danthonia*).

Prior to the harvesting and regeneration treatments, some plots also had some young eucalypt seedlings and saplings present. However, this advance growth was no longer present following the treatments and all subsequent eucalypt regeneration resulted from the aerial sowing and, in some cases, from seed falling from a few unmerchantable oldgrowth trees which remained after harvesting and survived the regeneration burn.

At the time of the assessment reported here, the age of the eucalypt regeneration was 21–22 years. The assessment was similar to that conducted at age 9–10 years (Elliott *et al.* 1991); that is, all eucalypt stems on each plot were counted and the eucalypt species present, diameter of stems greater than 5 cm DBH and the mean dominant height (MDH) for the plots were recorded. Basal areas and volumes over bark were derived for each plot from these data. Site index (defined as estimated MDH at age 50 years) was calculated using the standard Forestry Tasmania formula below. Note that mean dominant height used in the site index formula was calculated as the mean height of at least 25 dominant trees on each 0.375 ha plot, whereas for normal broad area Forestry Tasmania assessments it is defined as the mean height of the tallest tree on each one-thirtieth of a hectare.

$$SI = \frac{\text{Mean Dominant Height}}{1.5^{*}\,[1 - \exp(-\,0.03604.\text{AGE}^{0.8735})]}$$

Results

Stocking

The total stocking of eucalypts on all plots is shown in Table 2 and compared with stocking of the unlogged forest and the regeneration at age 9–10 years. Current stockings ranged from 701–3613 stems/ha, with the reduction in stocking in the 12 years since the last measurement ranging from 4.9% to 54.3%. Current stocking rates are 3.5–26 times those of the unlogged forest, with all plots having a good coverage of eucalypts and understorey species. Photos 1–3 and 4–6 track the changes in appearance in two example plots from the unlogged forest through the logging and burning treatment to the current regenerated forest.

Composition of the eucalypt species

The species composition of all eucalypt stems on the plots is shown in Table 3 together with the species composition of the plots at the previous assessment at age 9–10 years (from Elliott *et al.* 1991). On a total stem basis, there have been some minor changes in the proportion of individual species on some plots compared to the previous measurement but the dominant species at age 9–10 are still dominant at age 21–22 years. Significant variations have occurred in SW48 / 1 where *E. viminalis* representation has increased from 32% to 51% while *E. delegatensis* has declined from 23% to 10%; in SW48 / 3 where *E. delegatensis* has declined from 28% to 17%; in TO54 / 2 where *E. obliqua* has increased from 32% to 44%; and in TO54 / 3 where *E. tenuiramis* has increased from 27% to 45%.

Figure 2 shows the current eucalypt species composition of stems greater than 5 cm compared with that of the unlogged forest, the sowing mix used to regenerate the coupes, and the earlier assessment of regeneration at age 9–10 years. There have been some major and several minor changes in species composition since the assessment at age 9–10 years, although in general most plots still have a species composition closer to the unlogged forest than to the sowing mix used to regenerate the coupes. Changes have varied from coupe to coupe as described below:

- In EL10, there has been little change in species composition since the 9–10 year assessment except in EL10 / 1 where the proportions of *E. sieberi* and *E. obliqua* have increased at the expense of *E. globulus* (present at less than 1% in the unlogged forest). Figure 2 shows that a small percentage of the peppermints in the unlogged forest in plot 3 were assessed as *E. pulchella*. However, following the comments of Williams and Potts (1996) and the appearance of the regeneration, it is probable that all the peppermint species on this plot were *E. amygdalina*.
- In both TO54 plots, the species composition of the regeneration at 21–22 years is still much closer to that of the unlogged forest rather than the sowing mix used to regenerate the coupe. Importantly, even though the sowing mix contained 30% *E. globulus* (off-site species not present in the unlogged forest), this species is not represented in the regeneration greater than 5 cm DBH.
- In SW48, there has been little change since the previous assessment except in plot 1 where the proportion of *E. viminalis* has increased at the expense of *E. delegatensis*, a species not present in the unlogged forest or in the prescribed sowing mix but possibly present in the latter as a contaminant of the *E. obliqua* fraction. In SW48 plots 2 and 3, which were peppermint / gum (*E. amygdalina* / *E. viminalis*) sites, sowing of 60% *E. obliqua* has not produced any significant representation of this species in the regeneration.
- In MC33, again there has been little change since the last assessment except that the proportion of *E. amygdalina* in plot 2 has increased and that of *E. obliqua* has decreased. Sowing of 25% *E. globulus* on all three plots has not resulted in any representation of this species in the regeneration greater than 5 cm DBH.

Growth

Key growth parameters of the eucalypt regeneration on the plots are shown in Table 4. Mean diameter over bark (stems > 5 cm) ranged from 10.5 cm (EL10 / 2) to 15.6 cm (SW48 / 1). Mean dominant heights ranged from 9.4 m (TO54 / 3) to 16.3 m (EL10 / 3) indicating a site index range for the plots of 15.2–26.1. Entire stem volumes (ESV) and mean annual increment (MAI)

Table 2. Eucalypt stocking in the unlogged forest and subsequent regeneration.

Plot	Stocking (stems / ha)		
	Unlogged forest	Regeneration 9–10 yr	Regeneration 21–22 yr
EL10 / 1	254	989	877
EL10 / 2	222	5437	3128
EL10 / 3	178	3509	2267
TO54 / 2	139	5579	3613
TO54 / 3	160	984	936
MC33 / 1	339	2547	1869
MC33 / 2	291	4544	2077
MC33 / 3	115	1147	888
SW48 / 1	109	1213	701
SW48 / 2	125	1419	904
SW48 / 3	238	1224	907

Table 3. Species composition (%) of all eucalypt stems at age 21–22 years. Species composition at age 9–10 years is given in brackets. Changes greater than 10% between assessments are in bold type. (Abbreviations: E. obl = E. obliqua; *E. del* = E. delegatensis; *E. sieb* = E. sieberi, *E. vim* = E. viminalis, *E. glob* = E. globulus, *E. amyg* = E. amygdalina, *E. ten* = E. tenuiramis)

Plot	*E. obl*	*E. del*	*E. sieb*	*E. vim*	*E. glob*	*E. ovata*	*E. amyg*	*E. ten*
EL10 / 1	41 (41)	2 (9)	44 (34)	2 (2)	4 (6)		7 (8)	
EL10 / 2	17 (14)	< 1 (1)	80 (82)	2 (2)	< 1 (< 1)		1 (1)	
EL10 / 3	40 (37)		30 (29)	11 (10)	2 (2)		17 (22)	
TO54 / 2	**44 (32)**	1 (7)		< 1 (1)	1 (1)	48 (56)	< 1 (< 1)	5 (3)
TO54 / 3	43 (50)	2 (6)		4 (11)	4 (6)	< 1 (< 1)	2 (0)	**45 (27)**
MC33 / 1	1 (2)	51 (52)		6 (5)	< 1 (< 1)		42 (41)	
MC33 / 2	1 (< 1)	16 (20)		18 (12)	1 (1)		64 (67)	
MC33 / 3	< 1 (1)	70 (75)		24 (16)	< 1 (1)		5 (7)	
SW48 / 1	28 (35)	**10 (23)**		**51 (32)**	< 1 (0)	< 1 (0)	10 (10)	
SW48 / 2	1 (3)	0 (1)		36 (32)	0 (< 1)	3 (< 1)	60 (63)	
SW48 / 3	5 (5)	**17 (28)**		10 (8)		< 1 (0)	68 (59)	

Table 4. Growth parameters of eucalypt regeneration at age 21–22 years.

Plot	DBH (cm) (mean ± s.e)	Basal area (m^2 / ha)	MDH (m) (mean ± s.e.)	Volume (m^3 / ha)*	MAI (m^3 / ha / yr)	Site index
EL10 / 1	11.6 ± 0.4	5.2	10.7 ± 0.3	25.5	1.2	17.2
EL10 / 2	10.5 ± 0.2	13.7	14.2 ± 0.4	79.6	3.8	22.7
EL10 / 3	12.3 ± 0.3	18.8	16.3 ± 0.4	117.8	5.6	26.1
TO54 / 2	10.6 ± 0.2	12.9	9.9 ± 0.2	56.9	2.6	15.9
TO54 / 3	12.5 ± 0.4	6.1	9.4 ± 0.3	27.5	1.3	15.2
MC33 / 1	11.6 ± 0.4	9.9	12.5 ± 0.3	48.4	2.2	20.1
MC33 / 2	11.6 ± 0.3	15.0	11.8 ± 0.5	72.8	3.3	19.0
MC33 / 3	13.3 ± 0.4	10.7	13.6 ± 0.8	65.7	3.0	21.9
SW48 / 1	15.6 ± 0.6	10.9	14.0 ± 0.3	64.4	2.9	22.4
SW48 / 2	14.3 ± 0.4	11.2	13.0 ± 0.5	62.4	2.8	20.9
SW48 / 3	13.7 ± 0.3	13.49	12.0 ± 0.4	71.1	3.2	19.3

*Entire stem volume

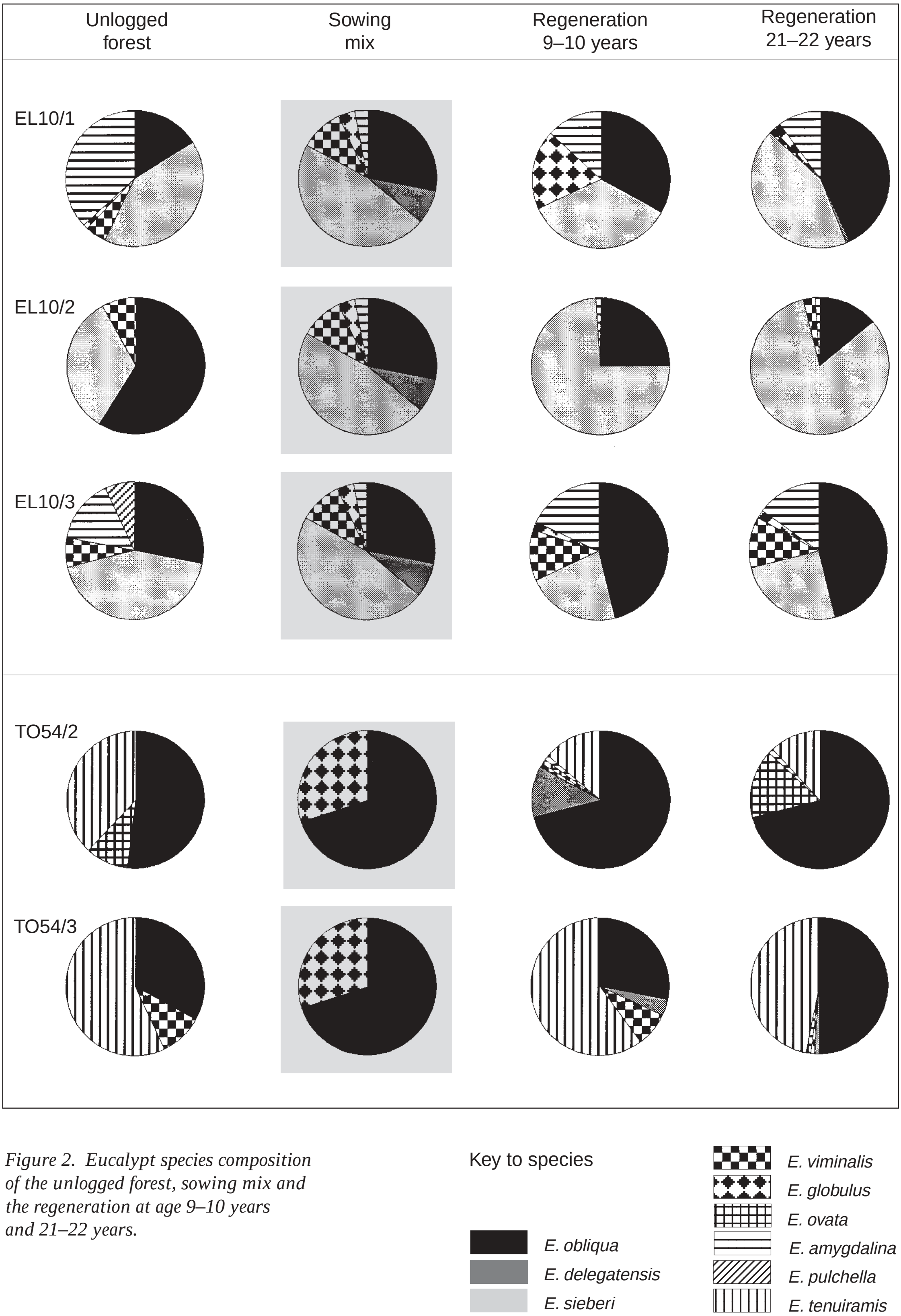

Figure 2. Eucalypt species composition of the unlogged forest, sowing mix and the regeneration at age 9–10 years and 21–22 years.

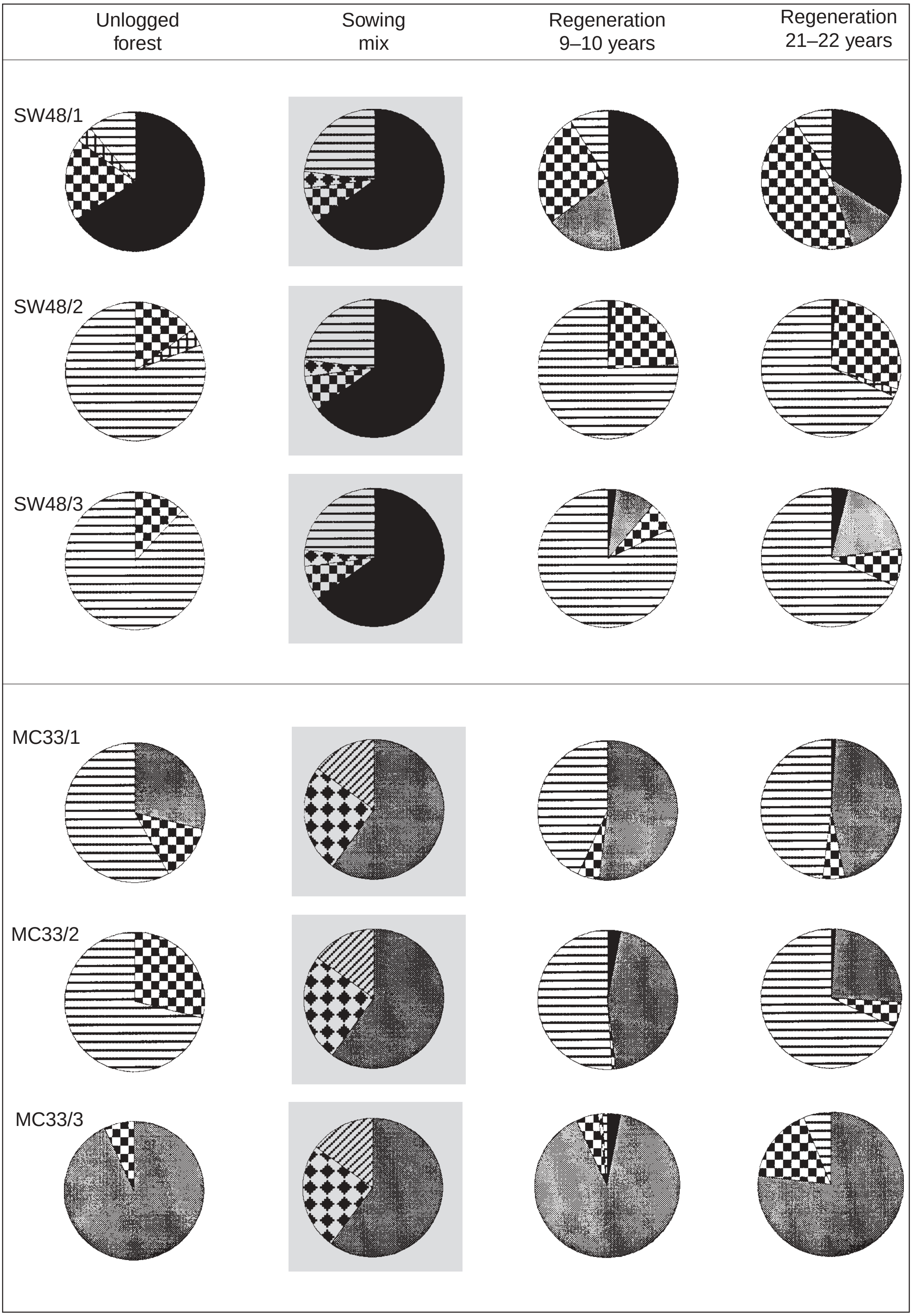
Unlogged forest
Sowing mix
Regeneration 9–10 years
Regeneration 21–22 years
SW48/1
SW48/2
SW48/3
MC33/1
MC33/2
MC33/3

Table 5. Basal area (m^2/ha) of unlogged forest and silvicultural regeneration at age 21–22 years.

Plot	Unlogged forest	Regeneration 21–22 yrs	Residual oldgrowth*
EL10/1	32.7	5.2	0
EL10/2	39.6	13.7	2.0
EL10/3	42.9	18.8	1.0
TO54/2	30.1	12.9	0
TO54/3	23.3	6.1	0.2
MC33/1	34.7	9.9	1.4
MC33/2	37.4	15.0	0
MC33/3	21.9	10.7	0.6
SW48/1	33.1	10.9	0.3
SW48/2	25.8	11.2	1.0
SW48/3	32.9	13.4	0.4

* Live remnants of the original forest present on the plot at the 21–22 year measurement.

ranged from 25.5 m^3/ha (EL10/1) to 117.8 m^3/ha (EL10/3) and 1.2–5.6 m^3/ha/yr respectively.

The basal area of all plots was recorded in 1977–78 before harvesting commenced and the regeneration on the plots at age 21–22 now has basal areas ranging from 16–49% (average 31.6%) of that of the original forest. Several plots still have a small number of live oldgrowth trees which survived the harvesting and regeneration process. When the basal area of these trees is included, the plots have an average of 38.1% (range 15.9–51.6) of the basal area of the original forest (Table 5).

Discussion

These dry eucalypt forest plots are the study areas for one of Tasmania's long-term ecological monitoring programs (Taylor 1999) and were established to enable a long-term (> 20 years) study of eucalypt growth, understorey vegetation and associated insect fauna. Such long-term plots, in which the species composition and growth can be followed from mature forest to later age regeneration on exactly the same site, are valuable for developing our understanding of forest dynamics and the effects of silvicultural practices.

At stocking levels of 701–3613 stems/ha at age 21–22, the plots generally have a good representation of eucalypt stems. Although stocking of this later age regeneration was not assessed against the Forestry Tasmania stocking standards, in terms of percentage of 4 m^2 plots stocked (Lockett and Mount 1991), no significant clumping of regeneration was evident during the assessment.

Although the composition of eucalypt species on some plots has changed, the dominant species are still generally the same as those recorded in the 9–10 year assessment. This result is a later age confirmation that the species composition of the eucalypt regeneration is generally closer to that of the unlogged forest than to that of the sowing mix used to regenerate the stand (Elliott *et al.* 1991), particularly where ash species were sown on peppermint/gum sites. Sowing of significant quantities of *E. globulus* on some coupes where it previously was not present or had very low representation also did not influence the species composition of the regenerated stand. As mentioned earlier, a few unmerchantable oldgrowth trees survived the harvesting and regeneration treatments on some plots. These trees can provide a continuing seed source and be important contributors to the regeneration. A good example of this is in plot TO54/2 where a few oldgrowth *E. ovata* are still present and even though no *E. ovata* was sown, this species now comprises some 16% of the regeneration.

The results of the species-composition studies emphasise the importance of recognising the species distribution within coupes and applying harvesting and regeneration systems which deliver natural patterns, albeit at an operational scale. In some cases where harvesting units contain strong species/site associations even over a small area, this may require application of separate sowing mixes to these sections of the coupe or, where

Photo 1. Plot MC33/1. Unlogged forest.

Photo 2. Plot MC33/1. During the logging operation.

Photo 3. Plot MC33/1. Regeneration at 21–22 years. Note the same scarred tree in the foreground as in Photo 2.

Photo 4. Plot MC33/2.
Unlogged forest.

Photo 5. Plot MC33/2.
After logging and burning.

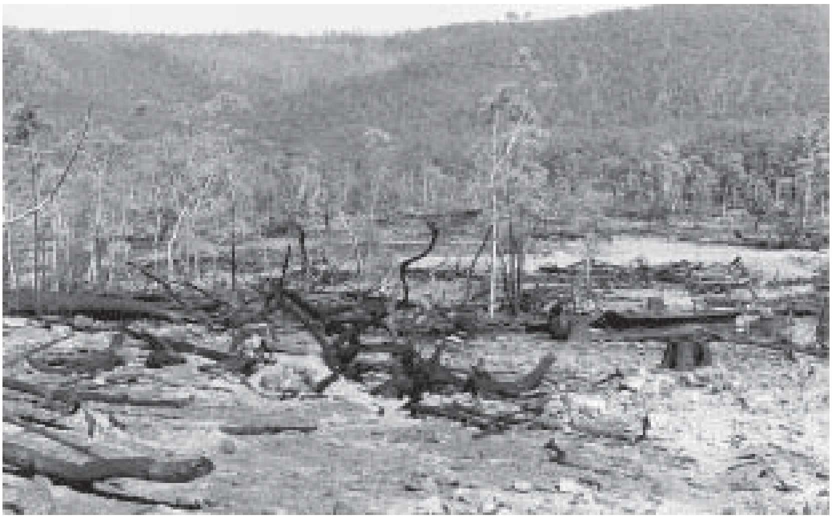

Photo 6. Plot MC33/2.
Regeneration at
21–22 years.

appropriate, retention of some stems as a continuing seed source.

It is important to note that the sowing mix for these forests was based on an assessment of the species composition of the unlogged forest on each harvesting unit (coupe) and only one sowing mix was used for each coupe. Consequently, any differences in eucalypt associations (e.g. due to aspect changes) within a coupe were not accounted for and on many coupes (generally much larger in area than current coupes) peppermint / gum stands were often sown with a significant component (sometimes 100%) of ash species. However, there was also some optimism at the time these coupes were harvested that the productivity of some sites could be improved by increasing the proportion of highly productive ash species such as *E. obliqua* or *E. delegatensis.* Such attempts to improve the productivity of dry forests have since been discontinued and actively discouraged under the *Forest Practices Code* (Forest Practices Board 2000) and regeneration success is also actively monitored under Forestry Tasmania's Quality Standards System.

Species composition of regeneration is an important factor in assessing regeneration success under Indicator 2.1g of the Montreal Process sustainability indicators. The results from the assessment of these plots at age 9–10 years (Elliott *et al*. 1991) have been used to show why species composition of regeneration inferred from sowing mixes is dubious (Lutze 2001). The later assessment reported here adds information relevant to Indicator 2.1g that species composition of regeneration will change over time.

Lockett and Goodwin (1999), working in the same forest block (Swanport) as three of the plots reported here (SW48 / 1–3), followed eucalypt growth from age 1 to age 16 over a range of stockings resulting from hand application at different sowing rates. Data from that study show that at age 16, plots with a similar range of stockings to those in the present study had broadly similar ranges of basal areas and height of dominant trees but at an earlier age (i.e. 16 years *vs* 21–22 years). The site index for their plots was higher, ranging from 22 to 32. The SW29 and SW30 sites used in their study have higher rainfall than SW48 (750 mm *vs* 585 mm) and this probably accounts at least in part for the better growth.

These lowland dry eucalypt forests can be expected to have a total stand volume MAI of 1–3 m^3 / ha / yr over a rotation of about 80 years (McCormick 1991). The MAIs at age 21–22 years of 1.2–5.6 m^3 / ha / yr found in this study indicate that growth over the rotation will be in the vicinity of the expected range. Estimation of the likely productivity of the regenerated forest at rotation age (likely to be 80–120 years; McCormick 1991) with that of the original forest on the same sites when the regeneration is only 21–22 years old is premature. However, it is noteworthy that several of the plots currently have 30–50% of the total stand basal area of the mature forest assessed before logging.

When the plots used in this study were established in the late 1970s, the clearfall, burn and sow treatment was commonly used in these drier forests. However, dry eucalypt communities in eastern Tasmania are generally uneven-aged, with a fire frequency of approximately 10–25 years (McCormick 1991) and, over recent years, uneven-aged management tailored to individual forest types has been practised (McCormick and Cunningham 1989). The plots currently have a predominantly even-aged structure resulting from the regeneration treatment used but this is likely to shift towards a more uneven-aged structure in the future as new cohorts of regeneration arise from periodic fire.

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References

Duncan, F. and Brown, M.J. (1985). *Dry Sclerophyll Vegetation in Tasmania*. Wildlife Division Technical Report 85/1. National Parks and Wildlife Service, Tasmania.

Elliott, H.J., Bashford, R. and Goodwin, A. (1991). Species composition, stocking and growth of dry eucalypt forest before and after logging in eastern Tasmania. *Tasforests* 3: 75–84.

Forest Practices Board (2000). *Forest Practices Code*. Forest Practices Board, Hobart, Tasmania.

Lockett, E.J. and Goodwin, A. (1999). Effects of initial stocking on stand development in even-aged mixed eucalypt regrowth: a preliminary model. *Australian Forestry* 62 (1): 9–16.

Lockett, E.J. and Mount, A.B. (1991). *Regeneration Surveys and Stocking Standards*. Native Forest Silviculture Technical Bulletin No. 6. Forestry Commission, Tasmania.

Lutze, M. (2001). Standardised measures of regeneration success for sustainable management of Australian native forest. WAPIS Project PN99.810 (Regeneration success measures and monitoring methods for sustainable forest management in native forest (Indicator 2.1g)). Centre for Forest Tree Technology, Orbost, Victoria.

McCormick, N.D. (1991). *Lowland Dry Eucalypt Forests*. Native Forest Silviculture Technical Bulletin No. 3. Forestry Commission, Tasmania.

McCormick, N.D. and Cunningham, J. (1989). Uneven-aged management in Tasmania's dry sclerophyll forests. *Tasforests* 1: 5–12.

MIG (1998). *A Framework of Regional (Sub-National) Level Criteria and Indicators of Sustainable Forest Management in Australia*. Montreal Process Implementation Group.

Senate Standing Committee on Science and the Environment (1977). *Woodchips and the Environment*. Report from the Senate Standing Committee on Science and the Environment. Australian Government Publishing Service, Canberra.

Taylor, R.J. (1999). *A Review of Long-term Ecological Monitoring in Tasmanian Forests*. A report to Forestry Tasmania and the Forest Practices Board. Division of Forest Research and Development, Forestry Tasmania.

Williams, K.J. and Potts, B.M. (1996). The natural distribution of *Eucalyptus* species in Tasmania. *Tasforests* 8: 39–165.